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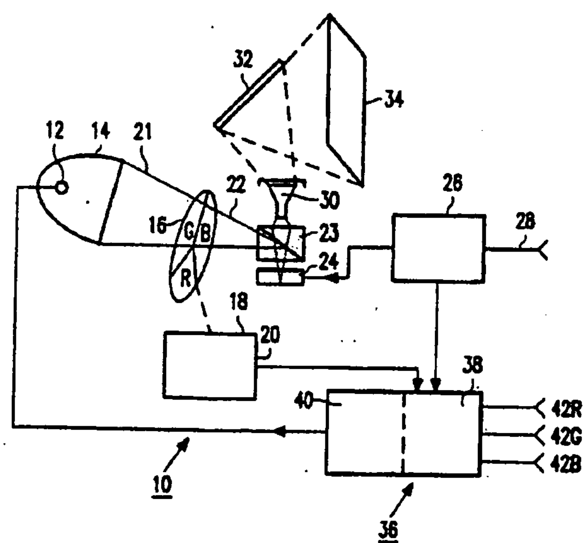
(54) Title: IMAGE PROJECTION DEVICE AND LAMP CONTROL SYSTEM FOR USE THEREIN



(57) Abstract

A color control system (10) for projection television displays having a projection lamp (12), a light valve (24) and means for varying the color of the light from the projection lamp, such as a color wheel (16). The color wheel driver (18) provides an output signal (20) which represents the position, that is the color, of the color wheel disposed in the lamp beam (21). The lamp driver means (36) varies the output power used to drive the lamp in response to the particular color (R, G, B) of the color wheel disposed in the beam. If the projection lamp has a deficiency in a certain color, the present system provides greater output power to the projection lamp during the presence of the filter for that color. A user input control (42) provides for changing the tint of the system based on user preferences and/or any changes occurring in the color filters or projection lamp.

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Image projection device and lamp control system for use therein.

An image projection device comprising:

a lamp, for emitting a beam of white light;

a light valve for modulating in accordance with a video signal light from the lamp impinging thereon;

means for varying the color of the beam of light emitted by said lamp, said color varying means being disposed between said lamp and said light valve.

Most commercially available image projection devices, like video projection devices utilize separate color channels for each of the three primary colors. Thus the system require red, green and blue light valves and optical paths which must be accurately converged on the screen. Recently, projection television devices utilizing only a single light valve have been developed. One such system is a color field sequential system, in which the normal video field, 1/60th of a second (16 ms), is broken into three parts, or color fields. These parts are normally equal length, so each color sub-field is 1/180th of a second (5.33 ms). Note that a 1/60 of a second video field is for 60 Hz NTSC systems, 50 Hz non-NTSC system would have a 1/50 of a second (20 ms) video field.

During the three color sub-fields, the light valve is illuminated with red, green and blue light sequentially. While the light valve is illuminated with any given color, the video data corresponding to that color is displayed on the light valve. The eye then fuses the three color sub-fields into a single, full color field. The eye also fuses successive video fields and frames into full motion, full color video. This system requires a device for sequentially illuminating the surface of the light valve with each of the three colors. The simplest of such devices is a rotatable color wheel which serves to change the color of a white projection lamp as it rotates.

Recently, improved light valves particularly suitable for use in image projection systems have become available. One such device is a so-called deformable mirror device (sometimes called a digital mirror device) which is illustrated in U.S. Patent No. 5,079,544 (the disclosure of which is hereby incorporated by reference as if fully set forth herein) and patents referenced therein, in which the light valve consists of a array of tiny movable mirrors for deflecting a beam of light either to the projection lens (on) or away

from the projection lens (off). By rapidly switching the mirror pixels on and off a grey scale can be generated. The mirror is quite small in physical size when compared to a comparable liquid crystal display cell. This device requires that all of the light of the projection lamp be focused on its relatively small surface which can limit the types of projection lamps useable in such a system. However, many otherwise suitable lamps may be deficient in color spectrum. Such lamps may also shift in color temperature as they age.

The color wheels for altering the color of the projection lamp are generally manufactured from dichroic filters. These filters suffer from certain drawbacks. The manufacture of dichroic filters is a batch process and there is a sample-to-sample variation in the colorimetry of these filters. Additionally, upon exposure to the intense light of the projection lamp the colors of the dichroic filters will fade. The present invention provides an image projection device wherein any color deficiencies are compensated. This device is characterized in that

the said color varying means have an output representative of the color applied to the beam of light;

the lamp driver means are capable of varying the intensity of said lamp in response to an input signal; and in that

lamp driver control means are provided for varying the output power of said lamp in synchronization with the color of the lamp provided by the output of said lamp color varying means.

The color wheel driver provides an output signal which represents the position, that is the color, of the color wheel to a lamp driver. The lamp driver is capable of varying the output power used to drive the lamp in response to the particular color of the color wheel segment presently in use. For example, if the projection lamp has a deficiency in a certain color the present system provides a larger output power to the projection lamp during the presence of the filter for that color. A user input control may be provided for changing the color balance of the system based on user preferences and/or any changes occurring in the dichroic filters or projection lamp. A closed loop technique may be used in which a detector senses the emitted color and automatically adjusts color balance.

The disclosure of U.S. Patent No. 5,079,544 makes reference to the use of a varying neutral density filter to vary the output power of the projection lamp during the course of the addressing of a single pixel. There is no disclosure of the varying of the power

to the projection lamp over an entire color. Thus, U.S. Patent No. 5,079,544 varies the output of the lamp on the order of microseconds while the present device operates on the order of milliseconds.

For better understanding of the invention reference is made to the detailed specification to follow which is to be taken in conjunction with the following reference figures;

Fig. 1 is a schematic diagram of the improved color control system for a color projection television system;

Figs. 2a -2f are diagrams of the various output waveforms used to provide drive power to the projection lamp in accordance with the invention; and

Figs. 3a and 3b illustrate driving waveforms which include a blanking period with intensity compensation for the off time.

Fig. 1 illustrates the color control system 10 for a color video projection system which includes a lamp 12 whose light output is directed by a reflector 14 to a color wheel 16. Color wheel 16 comprises three 120° segments of dichroic filters of different colors, in this case red, green and blue. Color wheel 16 is mounted for rotation about its axis and is driven by a wheel drive system 18 which includes an output 20 which represents the position of color wheel 16 and thus the particular color that is positioned in the output beam 21 of lamp 12. Thus, output beam 22 from the wheel is sequentially red, green and blue. Output beam 22 is directed by beamsplitter 23 to the surface of a light valve 24, which in this example is a deformable mirror device. The incoming beam 22 of colored light is modulated in accordance with the video information supplied to light valve 24 by a light valve drive 26 which receives its video information from a video input 28. The modulated beam of colored light reflected from the surface of light valve 24 is focused by a projection lens 30 onto a mirror 32 and reflected to a viewing screen 34. In operation, each color is sequentially projected onto the light valve, modulated by light valve 24 with the particular video information for that color and projected on screen 34. The sequence of color images occurs so rapidly that the eye integrates the separate images into a full color picture.

The present lamp driver system permits compensation for any color deficiency in lamp 12 as well as for adjustment to compensate for variations in the color of

the dichroic filters used in color wheel 16, as will be discussed in detailed below. The lamp driver system provides that the average power to the lamp remains constant and that the power in the positive pulses to the lamp equals the power in the negative pulses. This prevents lamp life deterioration due to the color compensating drive scheme.

Many different configurations for providing current output to drive lamp 12 are possible. Fig. 1 shows one configuration utilizing a voltage output square wave generator coupled to a current amplifier whose current output follows the voltage input. Fig. 1 shows lamp driver system 36 as comprising a signal generator 38 which is capable of providing voltage waveforms which are used to drive a current (power) amplifier 40 which supplies output power to lamp 12. An input to signal generator 38 is the control signal 20 of wheel drive 18 which provides synchronization of the position of color wheel 16 (and thus the color segment of color wheel 16 that is positioned in the light beam) with the lamp driver signal. Additionally connected to signal generator 38 are user input controls 42_R, 42_B, 42_G which permit the user to adjust the relative amount of red, blue and green in the output signal.

Figure 2 shows various pulse drive modes for lamp 12. In each case the signal is generated by signal generator 38 applied to current amplifier 40, and the output current supplied by amplifier 40 follows the waveform of signal generator 38. Lamp intensity follows current output so that when the current output is higher, the light intensity will be higher. Figure 2a depicts a standard (non color corrected) output waveform. In Figure 2a the first positive going pulse is applied to lamp 12 when the red segment of color wheel 16 is disposed in light beam 21. When the output signal 20 of wheel drive 18 indicates that the green segment of color wheel 16 is in position a negative pulse is thereafter generated and when the blue segment is positioned in beam 21 a positive pulse is generated. As is seen in Figure 2a all of the pulses, both positive and negative, for each color, have equal amplitude. Each video field, comprising red, green and blue pulses is 1/60 second (16 ms) with each color field 1/180 second. In this mode of operation if lamp 12 is deficient in a certain color the resulting displayed picture will also be deficient in that certain color. Additionally, as long as all of the pulses remain of equal amplitude no electrical lamp adjustment can be made for the color temperature as the system ages.

The waveforms shown in Figures 2b, 2c and 2d demonstrate the means for compensation of color deficiency as well as for adjustment of the white color temperature. In Figure 2b a second mode of operation is shown in which the pulses switch polarity after each color field. As is seen the amplitude of the red pulses (both positive and

negative) are greater than that of the blue pulses and the blue pulse's amplitude is greater than that of the green pulses. This will compensate for a red deficient lamp (by increasing intensity when the red portion of color wheel 16 is disposed in beam 21) and provide white balance to the output of the display system. By means of user input controls 42_R, 42_G and 42_B the red, green and blue pulse amplitudes are separately adjustable and are the same for the positive and negative portions of the cycle.

The waveforms shown in Figure 2c have the same output result of that as shown in Figure 2b. However, in Figure 2c only two of the three drive pulses to the lamp are of the same polarity and alternate video fields switch polarity. The waveform shown in Figure 2b and that of Figure 2c are fully equivalent in terms of their ability to adjust the white color temperature in a system with three primary colors. In a system with an even number of primary colors (i.e. cyan and magenta) the output device must operate in accordance with Figure 2c in order that the power in the positive pulses equal the power in the negative pulses. It is generally preferable to use the output waveforms as shown in Fig. 2b as these pulses are at a higher frequency (as measured by the zero crossing) than that of Fig. 2c. This prevents a perception of "pulsing" by the viewer.

Figures 2d, 2e and 2f show the output power for an image projection system in which three separate lamps are used in place of the single lamp 12. In such an arrangement, the single lamp 12 is replaced by three lamps, one for each of the primary colors. However, these systems are subject to the same problems as that of the single lamp system. The lamps may be deficient in a particular color or colors and the filters may vary or fade. In this mode, each lamp receives a series of pulses, timed so as to actuate only a single lamp. The pulses are varied in current amplitude so as to vary the color output to provide color correction or to adjust to user preference. As is seen this control scheme permits the output power of the various lamps to be altered so as to provide white balance on the screen.

Figs. 3a and 3b illustrate waveforms which provide a "blanking interval" in the light output of projection lamp 12. When a beam of white light is interrupted by a color wheel, two colors may be illuminated simultaneously or incorrectly alternated. This may be corrected by turning the lamp off during the error period ("blanking period" BP in Figs. 3a and 3b) and increasing the intensity of lamp 12 during its on period (intensity correction IC in Figs. 3a and 3b) to compensate for the power lost. Fig. 3a illustrates the blanking period waveform with intensity compensation in which there is a zero crossing (+/-) between colors and Fig. 3b illustrates the waveform without a zero crossing until all three

colors have been displayed. This blanking period may also be used to "mask" periods when light valve 24 is being loaded with data.

The above-described embodiments are merely illustrative of the principles of the present invention. Numerous modifications and variations thereof will be readily apparent to those skilled in the art without departing from the spirit and scope of the present invention.

CLAIMS:

1. An image projection device comprising:

a lamp for emitting a beam of white light;

a light valve for modulating in accordance with a video signal light from the lamp impinging thereon;

means for varying the color of the beam of light emitted by said lamp, said color varying means being disposed between said lamp and said light valve; characterized in that

the said color varying means have an output representative of the color applied to the beam of light;

the lamp driver means are capable of varying the intensity of said lamp in response to an input signal; and in that

lamp driver control means are provided for varying the output power of said lamp in synchronization with the color of the lamp provided by the output of said lamp color varying means.

2. An image projection device as claimed in Claim 1 wherein said means for varying the color of the beam of lamp comprises a color wheel.

3. An image projection device as claimed in Claim 1 or 2 wherein said lamp driver means control lamp intensity by varying the current to said lamp.

4. An image projection device as claimed in Claim 2 wherein said color wheel comprises light transmissive dichroic filters.

5. An image projection device as claimed in Claim 1, 2, 3 or 4 wherein said light valve comprises a deformable mirror device having an array of pixels for modulating the light impinging thereon.

6. An image projection device as claimed in Claim 1, 2, 3, 4 or 5 wherein the lamp driver means varies the intensity of the lamp by varying the current supplied thereto.

7. An image projection device as claimed in Claim 6 wherein the lamp driver means output is a square wave.

8. An image projection device as claimed in Claim 7 wherein the color varying means switch the light between three colors and the amplitude of the square wave is different for at least one of the colors as compared to the other colors.

9. An image projection device as claimed in Claim 8 wherein the polarity of the square wave switches between each of the three colors.

10. An image projection device as claimed in Claim 8 wherein the polarity of the square wave remains the same during each image field composed of the three colors.

11. An image projection device as claimed in Claim 8 wherein during the transition between two differing colors the power to the lamp is turned off.

12. An image projection device as claimed in any of the preceding Claims wherein said lamp driver control means includes means for further varying the output power to the lamp in response to user preference.

13. A lamp control system for use in a color image projection device, characterized by any of the features of claims 1-12 relevant to the lamp control system.

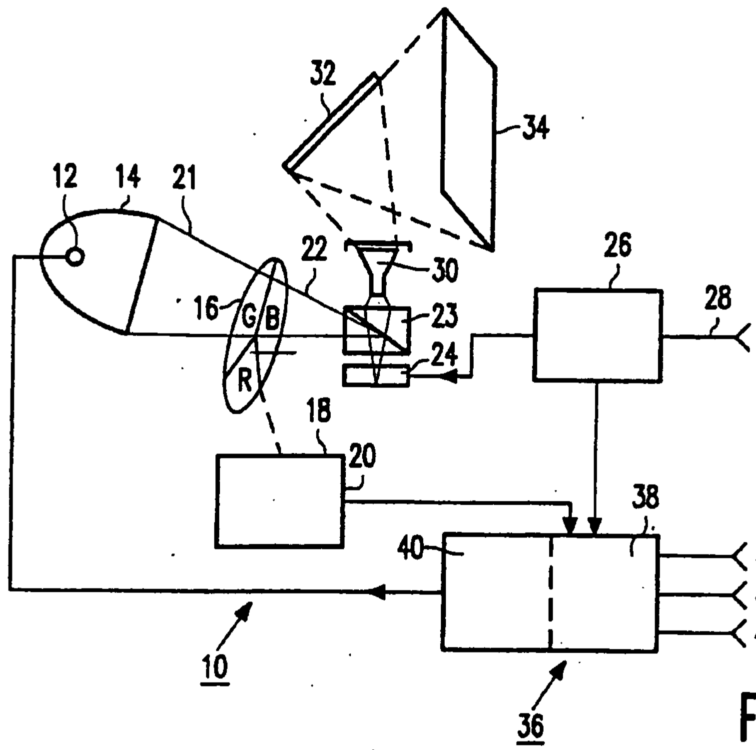

FIG. 1

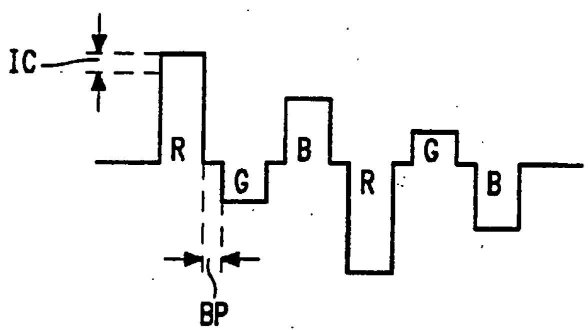

FIG. 3a

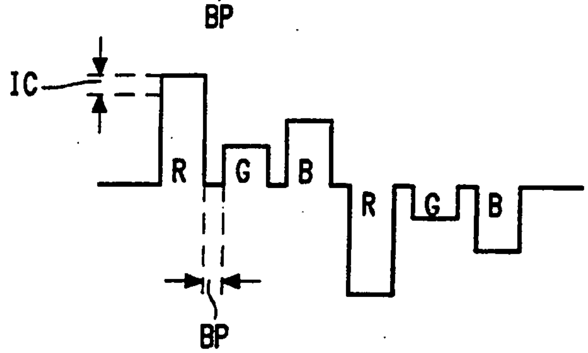

FIG. 3b

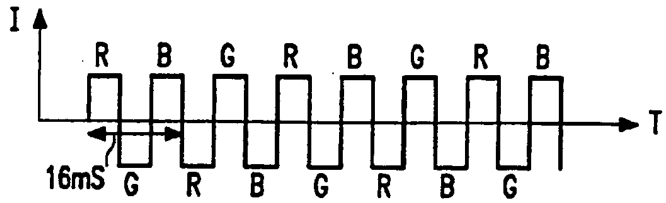

FIG. 2a

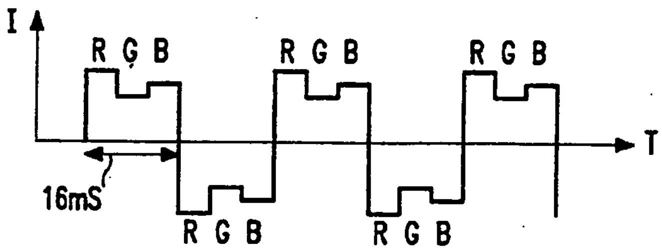

FIG. 2b

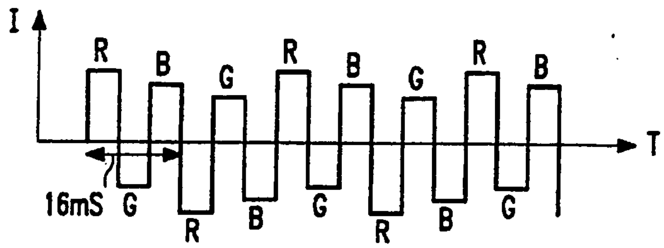

FIG. 2c

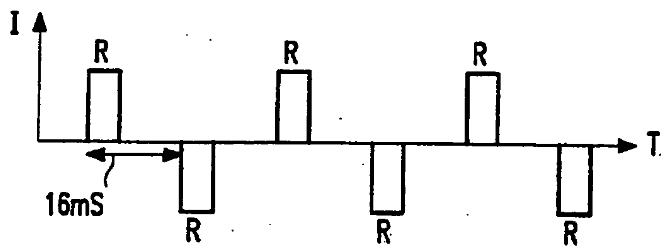

FIG. 2d

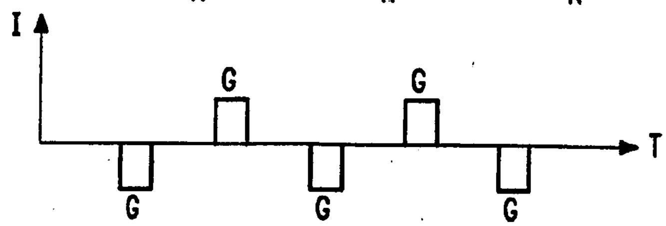

FIG. 2e

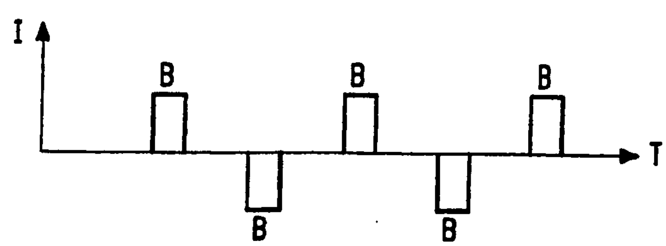

FIG. 2f

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB 94/00323

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H04N 9/14, H04N 9/31

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, A, 4974095 (ANATOLY AROV), 27 November 1990 (27.11.90), column 1, line 56 - line 61; column 3, line 31 - line 33; column 4, line 26 - line 49, figure 4, abstract	1,13
Y		2,3,5-8, 10-12
A		4,9
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Y	EP, A2, 0391529 (TEXAS INSTRUMENTS INCORPORATED), 10 October 1990 (10.10.90), column 17, line 28 - column 18, line 48; column 8, line 42 - line 53	2,5
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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
28 March 1995	29 -03- 1995
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Bertil Ljungdahl Telephone No. +46 8 782 25 00

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International application No.
PCT/IB 94/00323

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT
Information on patent family members

25/02/95

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